Clustering of health-related behaviors among early and mid-adolescents in Tuscany: results from a representative cross-sectional study

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ABSTRACT

Background A huge amount of literature suggests that adolescents' health-related behaviors tend to occur in clusters, and the understanding of such behavioral clustering may have direct implications for the effective tailoring of health-promotion interventions. Despite the usefulness of analyzing clustering, Italian data on this topic are scant. This study aimed to evaluate the clustering patterns of health-related behaviors.

Methods The present study is based on data from the Health Behaviors in School-aged Children (HBSC) study conducted in Tuscany in 2010, which involved 3291 11-, 13- and 15-year olds. To aggregate students' data on 22 health-related behaviors, factor analysis and subsequent cluster analysis were performed.

Results Factor analysis revealed eight factors, which were dubbed in accordance with their main traits: 'Alcohol drinking', 'Smoking', 'Physical activity', 'Screen time', 'Signs & symptoms', 'Healthy eating', 'Violence' and 'Sweet tooth'. These factors explained 67% of variance and underwent cluster analysis. A six-cluster κ-means solution was established with a 93.8% level of classification validity. The between-cluster differences in both mean age and gender distribution were highly statistically significant.

Conclusions Health-compromising behaviors are common among Tuscan teens and occur in distinct clusters. These results may be used by schools, health-promotion authorities and other stakeholders to design and implement tailored preventive interventions in Tuscany.

Keywords methods, public health, young people

Background

Priority health-compromising behaviors, which usually begin in adolescence, shape future adult behavior and are associated with an increased risk of morbidity and premature mortality, and thus high societal costs.[1,2] As in other industrialized societies, risk factors such as smoking, alcohol use, insufficient consumption of fruit and vegetables and excessive screen time are highly prevalent among Italian teenagers.[3] These single unhealthy behaviors may be either interrelated or unrelated, and distinguishing between them is of practical significance. Indeed, public health interventions targeting single unhealthy behaviors could have an impact on unrelated behaviors, while the effect of similar interventions on interrelated behaviors will probably be far from

optimal.[4] Nevertheless, Italian research on adolescent health promotion has often focused only on some epidemiological features of single unhealthy behaviors.[5–8]

Today, there is considerable evidence that unhealthy behaviors, especially, the so-called 'big four': tobacco smoking,

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alcohol abuse, unhealthy diet and physical inactivity, may simultaneously involve the same subject.[9–14] Indeed, a remarkable feature of health-related behaviors is their tendency to occur in clusters,[15] and such clusters are not randomly distributed at the population level.[16] Although studies on single health behaviors are able to highlight the relationship between a variable of interest which, however, requires prior classification and other health behaviors, they do not enable us to evaluate the role of single behaviors in determining clusters.[4]

Cluster and factor analyses are two distinct, powerful, multivariate tools and should be used complementarily rather than separately. Indeed, factor analysis enables us to find common dimensions within which a variable may be located, while clustering enables group membership to be established.[17] For these reasons, factor and cluster analyses are among the most widely used techniques in the behavioral sciences[18] and have been amply applied in order to explore health behaviors during adolescence (reviewed in Refs[19,20]). For instance, in their comprehensive review on obesogenic cluster patterns among children and adolescents, Leech et al.[20] concluded that diet, physical activity and a sedentary lifestyle cluster together in very complex ways, and that cluster membership depends on age, sex and socio-economic status. A systematic review by Wiefferink et al.[19] explored the clustering of four behaviors namely, smoking, alcohol abuse, safe sex and healthy nutrition and revealed that smoking clusters with alcohol abuse (correlations of 0.43–0.60), while sexual experience clusters with both smoking and alcohol abuse (correlations of 0.29–0.54). The large Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) cross-sectional study[21,22] identified five clusters among adolescents in European cities. In these studies, clear age and gender differences in clustering patterns were observed. In comparison with older adolescents, younger ones are more physically active and have a healthier diet[21]; males display a pattern of high levels of moderate/vigorous physical activity and low-quality diets, while females display an opposite pattern.[22]

Although research conducted in various geographical settings, including Europe,[21,22] has identified similar clusters of health behaviors among teenagers, it is not known whether the results of these studies can be transferred to the Italian context. Indeed, unhealthy behaviors are subject to a certain level of cross-cultural variation.[23] We previously investigated[24] factors associated with health-related behaviors among school-aged children in Tuscany. These data, however, may not be enough to design and implement well-targeted health-promotion interventions; indeed, some groups of teens may gain no, or less, benefit from 'universal' health-promotion campaigns, thus increasing inequalities. Taking these considerations into account, we aimed to examine the clustering of health-related behaviors among Italian teenagers and thereby to identify patterns of behavior clusters.

Methods

Source of data

The data used in the present study are from a WHO-promoted cross-national Health Behaviors in School-aged Children (HBSC) study carried out in Tuscany in 2010. The detailed methodology and survey tools used to collect these data are reported elsewhere.[25] Briefly, data were gathered on a 4-year basis from adolescents aged 11–15 years (specifically, 11-, 13- and 15-year olds); the cluster sampling strategy was applied to obtain a random sample of school classes. The questionnaire used was self-administered (in the presence of trained personnel) in schools, in accordance with international standards.[26] Of note, the questionnaire is subject to continuous development and validation by all participating countries. Parental approval of children's participation in the study was mandatory. The study protocol was approved by the Ethics Committee of the National Institute of Health; a parental opt-out consent form was used. All data were gathered anonymously, so that single participants could not be identified.

Health-related behaviors of interest

In this study, multiple health-related (both health-compromising and health-protective) behaviors were analyzed. Items on physical activity included both frequency (N of times for at least 60 min) and duration (N of hours). These items were accompanied by a brief student-friendly definition of physical activity. Dietary behavior was quantified by asking students how often they consumed fruit, vegetables, sweets and sweetened beverages. The recall period for physical activity and dietary patterns was set to 7 days. Sedentary behavior patterns were assessed by means of items on the frequency of prolonged (>2 consecutive hours) screen time (watching television/DVD, using the computer to chat, surf the web etc., playing video/computer games).

Questions on smoking included both past smoking experience and current smoking (frequency and number of cigarettes smoked in the past 30 days). Alcohol-related behavioral patterns were assessed both by type of alcoholic beverages (beer, wine, spirits/liquors, alcopops and other drinks) and by the frequency of their use.

Violent behavior was evaluated through two items on the frequency of participation in fights in the last 12 months

and engaging in bullying in the last 2 months. The frequency of somatic and psychological symptoms (headache, stomach ache, backache, feeling sad, being irritable/in a bad mood/nervous, difficulty in falling asleep, dizziness) was also investigated (recall period of 6 months).

In sum, data on 22 health-related behaviors (5 protective and 17 health-compromising) were collected; the number of response options (levels) varied by item, as shown in Table 1.

Statistical analysis

For descriptive purposes, all frequency data were reported as percentages. Factor and subsequent cluster analyses were performed as described by Yen et al.[27] Since the original scales of measurement (response options) varied by item, the variables were first standardized. Factor analysis was made as follows. Preliminarily, sampling adequacy was verified by means of Bartlett's test of sphericity and overall Kaiser–Meyer–Olkin (KMO), while the presence of multi-collinearity was checked by the determinant of correlation matrix. KMO must not be <0.5, while values of 0.8 and higher are considered optimal.[28] To identify factors, determine their scores and uncover the latent structure, principal-component analysis with varimax orthogonal rotation was performed. The number of factors was determined by applying Kaiser's eigenvalue cutoff of 1. Factor loading plots

Table 1 Distribution (%) of health-related behaviors among Tuscan adolescents

Behavioral item	N	0/we	<1/we	1/we	2–4/we	5–6/we	1/d	>1/d
Eating fruit, times/period	3283	4.6	8.2	9.6	24.4	12.4	21.2	19.6
Eating vegetables, times/period	3274	7.0	7.0	12.7	27.4	16.9	16.6	12.4
Eating sweets, times/period	3259	3.3	13.1	17.7	25.6	14.3	13.3	12.7
Drinking sweetened beverages, times/period	3208	44.7	20.9	13.5	10.7	4.4	3.3	2.5
		0	*1*	*2*	*3*	*4*	*5*	*6–7*
Physical activity in the last we, d	3257	6.0	9.4	19.7	19.4	17.4	12.3	15.7
		0/mo	*<1/mo*	*1/mo*	*1/we*	*2–3/we*	*4–6/we*	*1/d*
Physical activity outside school, times/period	3273	10.1	3.7	4.5	13.0	40.2	21.2	7.3
		0	*0.5*	*1*	*2–3*	*4–6*	*≥7*	
Physical activity outside school, h	3275	13.3	10.0	20.2	29.5	16.4	10.7	
		0	*0.5*	*1*	*2*	*3*	*4*	*5–7*
Use of pc, h/d	3278	19.7	17.9	23.6	17.1	10.0	5.6	6.1
Watching TV, h/d	3274	5.5	14.8	26.1	26.1	14.5	6.8	6.2
Video/pc gaming, h/d	3269	25.3	21.4	24.0	16.2	6.2	3.1	3.7
		No	*Yes*					
Smoking experience	3271	78.0	22.0					
		0/we	*<1/we*	*≥ 1/we <1/d*	*≥1/d*			
Frequency of current smoking, times/period	3278	89.0	3.1	3.0	4.8			
		0	*< 1/we*	*< 1/d*	*1–5/d*	*6–10/d*	*11–20/d*	*> 20/d*
Number of cigarettes smoked in the last 30 d	3267	88.3	3.6	1.6	3.3	1.7	0.9	0.5
		Never	*Rarely*	*Every mo*	*Every we*	*Every d*		
Drinking beer	3234	67.3	22.1	3.1	6.6	0.9		
Drinking wine	3230	67.3	22.1	3.4	4.8	2.4		
Drinking spirits/liquors	3201	79.8	13.9	2.8	3.2	0.3		
Drinking alcopops	3209	65.4	22.6	5.7	5.3	1.0		
Drinking other drinks	3216	70.6	17.8	5.1	5.9	0.7		
		0	*1*	*2*	*3*	*≥4*		
Participation in a fight in the last 12 mo, times	3272	67.1	16.7	6.2	3.3	6.7		
		0	*1–2/mo*	*2–3/mo*	*1/we*	*>1/we*		
Being a bully in the last 2 mo, times/period	3267	85.2	10.7	2.0	0.6	1.4		
		Never/rarely	*1/mo*	*1/we*	*>1/we*	*>1/d*		
Somatic symptoms (≥1), times/period	3279	12.3	22.8	20.2	25.6	19.1		
Psychological symptoms, (≥1), times/period	3275	8.5	20.4	24.8	29.6	16.7		

d, day; h, hour; mo, month; we, week.

were also examined. The factors identified were named according to their core components.

Cluster analysis was then performed in order to classify subjects according to their health-related behaviors. First, hierarchical clustering was analyzed by means of Ward's method, which uses squared Euclidean distance as a similarity measure. Subsequently, in order to maximize within-group similarities and find clusters, the κ-means algorithm for non-hierarchical clustering was computed to establish the final set of clusters. Scheffé's test was used to make multiple comparisons.

Each cluster was characterized in terms of dimension, age and sex distributions; the between-cluster differences in the age and sex distributions were formally tested by means of one-way analysis of variance and χ^2 test, respectively.

Statistical significance was set to two-sided $\alpha < 0.05$. All analyses were carried out by means of SPSS statistical software, version 20.0 (SPSS Inc., Chicago, IL).

Results

Characteristics of study subjects

The socio-demographic characteristics of the participants have been reported elsewhere.[24]

The distributions of students' health-related behaviors are reported in Table 1. Approximately, a quarter of adolescents ate fruit [22.4% (95% confidence interval, CI: 21.0–23.9%)] and vegetables [26.7% (95% CI: 25.2–28.2%)] only once a week or less, while 40.3% (95% CI: 38.6–42.0%) ate sweets at least 5 times a week. Similarly, most students did not exercise at all, or else much less than recommended (≥1 hour/day). With regard to screen-time entertainment, 21.7% (95% CI: 20.3–23.1%), 27.5% (95% CI: 26.0–29.0%) and 13.0% (95% CI: 11.9–14.2%) spent >2 hours per day using the computer, watching television and playing video games, respectively.

More than a fifth [22.0% (95% CI: 20.6–23.5%)] had experience of smoking, while 10.9% (95% CI: 9.9–12.0%) were defined as current smokers. About two-thirds of teens had never drunk beer [67.3 (95% CI: 65.7–68.9%)], wine [67.3 (95% CI:65.7–68.9%)] or alcopops [65.4 (95% CI: 63.8–7.0%)]. In the previous year, a third [32.9% (95% CI: 31.3–34.5%)] of adolescents had participated in a fight at least once. Engaging in bullying at least once in the previous 2 months was reported by 14.8% (95% CI: 13.6–16.1%) of students.

Somatic and psychological symptoms were also very prevalent: 87.7% (95% CI: 86.5–88.8%) and 91.5% (95% CI: 90.5–92.4%) of teens had at least one somatic or psychological symptom, respectively, at least once a month.

Factor analysis

As shown by the KMO coefficient of 0.80, the highly statistically significant Bartlett's test ($\chi^2_{231} = 20\,178.51$, $P < 0.001$) and determinant of correlation matrix (0.001), the factor analysis was suitable. A total of 8 factors with eigenvalues >1 were identified and named according to their main traits. Specifically, Factors 1 ('Alcohol drinking') and 2 ('Smoking') included items on the frequency of consumption of various alcoholic beverages, previous smoking experience, frequency of current smoking and number of cigarettes smoked. These two factors explained 21.1 and 11.0% of variance, respectively. Factor 3 had loadings on three items on physical activity, including both frequency and duration ($R^2 = 0.08$), while Factor 4 ('Screen time') had loadings on frequency items forming sedentary behavior patterns, and displayed an explained variance of 5.9%. The remaining four factors all included two loadings [Factor 5 'Signs & symptoms' (frequency of somatic and psychological symptoms), Factor 6 'Healthy eating' (frequency of consumption of fruit and vegetables), Factor 7 'Violence' (frequency of participation in fights and active bullying) and Factor 8 'Sweet tooth' (frequency of consumption of sweets and soft drinks)]. Cumulatively, the eight factors explained 67% of variance. Each of the 22 behaviors displayed some degree of common variance with other behaviors, since all communalities exceeded 0.5 (Table 2).

Cluster analysis

The optimal number of clusters was identified as follows. An increase in agglomerative coefficients (Δ of 17.8%) was observed when the eight clusters were reduced to seven. Further reduction to six groups produced an even higher increase (Δ of 19.7%) in agglomerative coefficients. The six-cluster κ-means solution was therefore established; the discriminant analysis confirmed a high (93.8%) level of validity of the classification. As shown by Sheffé's test statistics, there were several significant comparisons among the eight behavioral factors; only scores for the 'Sweet tooth' factor were not significantly related to the other clusters.

As reported in Table 3, Cluster 1 had the highest positive score (2.26) for the factor 'Violence' and was named 'Violent group'. Cluster 2 'Non-drinking smokers group' showed a high z-score for the factor 'Smoking' and a very low score for 'Alcohol drinking', while Cluster 3 was dubbed 'Smoking drinkers group' owing to the high scores for both factors. Cluster 4 was judged to be the healthiest, as its scores on health-compromising factors were either negative or close to zero, while those on both protective behaviors were negative; it was therefore named 'Quasi-healthy group'. Clusters 5 and 6

Table 2 Factor analysis of 22 health-related behaviors among Tuscan adolescents

Behavior	Factor names	Factors								Communalities
		1	2	3	4	5	6	7	8	
Frequency of drinking beer	Alcohol drinking	**0.757**	0.208	−0.020	−0.035	−0.004	0.023	−0.113	0.044	0.63
Frequency of drinking wine		**0.761**	−0.062	−0.026	−0.027	−0.036	−0.033	−0.148	0.047	0.61
Frequency of drinking spirits/liquors		**0.677**	0.334	−0.012	−0.065	0.059	0.019	−0.034	−0.060	0.58
Frequency of drinking alcopops		**0.697**	0.169	−0.035	−0.108	0.097	0.014	−0.035	−0.127	0.55
Frequency of drinking other alcoholic drinks		**0.728**	0.371	−0.009	−0.088	0.078	0.040	0.003	−0.071	0.69
Smoking experience	Smoking	0.378	**0.674**	0.008	−0.114	0.099	0.046	−0.003	−0.014	0.62
Current smoking frequency		0.233	**0.914**	0.056	−0.020	0.036	0.024	−0.091	−0.015	0.90
Cigarettes smoked in the last 30 days		−0.239	**−0.903**	−0.054	0.044	−0.029	−0.046	0.121	0.026	0.89
Frequency of physical activity in the last week	Physical activity	−0.027	0.048	**0.800**	−0.016	0.015	0.044	0.034	0.011	0.65
Frequency of physical activity outside school		−0.006	−0.039	**−0.888**	0.056	−0.039	−0.075	−0.066	−0.028	0.80
Hours of physical activity outside school		−0.058	0.002	**0.865**	−0.012	0.075	0.037	−0.004	0.002	0.76
Daily hours of TV watching	Screen time	−0.028	0.004	−0.057	**0.704**	0.002	−0.006	0.073	0.125	0.52
Daily hours of playing video games		−0.059	−0.001	−0.006	**0.788**	0.022	−0.116	0.193	0.023	0.68
Daily hours of pc use		−0.169	−0.170	−0.014	**0.723**	−0.156	−0.038	−0.082	0.016	0.61
Frequency of somatic symptoms	Signs & symptoms	0.052	0.061	0.012	−0.014	**0.834**	0.042	−0.018	−0.018	0.70
Frequency of psychological symptoms		0.062	0.053	0.110	−0.086	**0.813**	0.015	−0.118	−0.022	0.70
Frequency of fruit consumption	Healthy eating	0.040	0.064	0.087	−0.064	0.046	**0.815**	−0.033	0.056	0.69
Frequency of vegetable consumption		−0.009	0.018	0.057	−0.067	0.010	**0.811**	−0.056	−0.119	0.68
Frequency of participation in fights	Violence	−0.132	0.002	0.069	0.081	−0.131	−0.087	**0.744**	0.050	0.61
Frequency of being a bully		−0.108	−0.166	0.021	0.089	−0.006	−0.004	**0.750**	0.033	0.61
Frequency of sweet consumption	Sweet tooth	−0.043	−0.025	0.034	0.131	−0.068	−0.229	−0.014	**0.685**	0.55
Frequency of soft drink consumption		−0.050	−0.020	0.005	0.037	0.025	0.138	0.095	**0.804**	0.68
Eigenvalue	—	4.66	2.41	1.83	1.30	1.28	1.16	1.06	1.02	—
R^2	—	0.212	0.110	0.083	0.059	0.058	0.053	0.048	0.046	—
Cumulative R^2	—	0.212	0.322	0.405	0.464	0.522	0.575	0.623	0.669	—

Loadings > |0.5| are evidenced in bold.

displayed their highest z-scores on the factors 'Signs & symptoms' (0.97) and 'Screen time' (1.88) and were therefore called 'Symptomatic' and 'Screen passion' groups, respectively.

There was a 4-fold difference in the dimensions of clusters: 'Symptomatic' and 'Smoking drinker' groups (31.3 and 29.7%, respectively) were the largest, while 'Quasi-healthy' and 'Violent' groups (7.8 and 9.5%, respectively) were substantially less copious (Table 4). Male students were more prevalent in 'Violent', 'Non-drinking smoker' and 'Symptomatic' groups. The 'Quasi-healthy' group comprised older students (mean age 15.2 years), while the 'Violent' cluster was composed of younger adolescents (mean age 12.8 years). The between-group differences in both mean age and gender distribution were highly statistically significant ($P < 0.001$) (Table 4).

Discussion

Main finding of this study

We found that early and mid-adolescents in Tuscany formed six clusters: namely, 'Violent', 'Non-drinking smoker', 'Smoking drinker', 'Quasi-healthy', 'Symptomatic' and 'Screen passion' groups; each of these showed a unique behavioral pattern. It is alarming that most Clusters (4 of 6) had higher than average scores of both 'Smoking' and 'Alcohol drinking' behaviors; this finding confirms a previously reported observation[19] that these two modifiable risk factors are among the commonest among adolescents and usually cluster together. This result is also of a great practical significance, since health-promotion interventions targeting both risk behaviors simultaneously would be beneficial to most students.

What is already known on this topic

Two clusters of alcohol consumers were established; these had very similar scores on all behaviors, except for diametrically opposite scores on the 'Signs & Symptoms' factor. Italy, being situated in the south of Europe, is a typical 'wine-drinking' country[30] and wine consumption is fairly common, especially during main meals.[31] Indeed, the European Comparative Alcohol Study (ECAS) revealed that Italy was the top country in Europe in terms of daily drinking (as opposed to binge drinking, which is more common in northern and central Europe)[30]; moreover, an increasing

Table 3 Comparison of z factor scores for the clusters identified

Behavioral factors	Cluster						F	Sheffé's test
	1	2	3	4	5	6		
Alcohol drinking	0.20	−2.00	0.37	−0.57	0.34	0.22	699.03*	3 > (1,2,4,6)
Smoking	0.22	0.61	0.20	−2.92	0.17	0.25	1635.79*	2 > (1,3,4,5,6)
Physical activity	0.14	0.16	0.01	−0.22	0.01	−0.16	6.50*	(1,2) > (4,6)
Screen time	−0.08	−0.08	−0.41	0.03	−0.22	1.88	482.71*	6 > (1,2,3,4,5)
Signs & symptoms	−0.22	−0.09	−0.79	−0.09	0.97	−0.29	571.72*	5 > (1,2,3,4,6)
Healthy eating	−0.14	−0.02	0.09	−0.13	0.02	−0.06	3.66*	3 > 1
Violence	2.26	−0.23	−0.27	−0.03	−0.25	−0.27	685.23*	1 > (2,3,4,5,6)
Sweet tooth	0.07	00.05	−0.03	00.05	−0.01	−0.06	0.919**	—

*$P < 0.001$; **$P > 0.05$.

Table 4 Dimensions, age and sex distributions of the six clusters

Cluster	Parameter		
	Dimensions, % (95% CI)	% boys (95% CI)	Mean age (SD), years
1: Violent group	9.5 (8.5–10.6)	75.7 (70.3–80.4)	12.8 (1.5)
2: Non-drinking smoker group	10.8 (9.7–12.0)	68.1 (62.7–73.0)	14.4 (1.4)
3: Smoking drinker group	29.7 (28.1–31.4)	35.0 (31.9–38.3)	13.0 (1.6)
4: Quasi-healthy group	7.8 (6.8–8.8)	40.7 (34.5–47.2)	15.2 (0.9)
5: Symptomatic group	31.3 (29.6–33.0)	56.6 (53.3–59.8)	12.9 (1.5)
6: Screen passion group	10.9 (9.8–12.1)	46.4 (41.0–51.9)	13.7 (1.5)

proportion of female and young daily drinkers in Italy has been also established.[32] Indeed, as the two above-mentioned clusters comprised 53.9% of girls, this finding confirms the increasing trend in alcohol consumption among female teens. On the other hand, it is interesting that the proportion of 'wine ever' drinkers (those who stated having tried wine at least once in their lives) was almost equal than that of 'beer and alcopops ever' drinkers. This observation is consistent with previously described[33] patterns on the internationalization of drinking habits (i.e. with a shift from the more traditional wine to alcopops or beer). Since teens may regard low-alcohol drinks as a 'healthier' alternative, tailor-made interventions should also highlight the potential dangers of such drinks. Taking into consideration that an average European adolescent begins to drink alcoholic beverages at the age of 12.5 years and gets drunk for the first time at 14 years,[30] it is essential to deliver age-tailored preventive interventions sufficiently early. An appropriate period could be around 11 years of age, which roughly corresponds to the transition from primary school to the first phase of secondary education. Indeed, it has already been shown[6] that this is the period when the risk of starting to smoke begins to increase.

As expected, the 'Violent' cluster was mostly composed of boys, although it also displayed a significant presence of girls (about a quarter); this means that careful attention should be paid to gender roles in the school environment. Moreover, this cluster had above-average scores on both 'Smoking' and 'Alcohol drinking'. A highly significant and consistent association between bullying and smoking/drinking has also been documented among Italian adolescents.[34] Since several health-compromising risk factors are difficult to identify in the school context, the violent behavior of students toward their peers could be regarded as a marker of other unhealthy behaviors, such as smoking or frequent alcohol consumption.[34]

About 11% of students fell into the 'Screen passion' group; inclusion in this cluster was also associated with high scores on 'Alcohol drinking' and 'Smoking'. A similar pattern has been observed in previous research[35–37] and may be explained by the fact that prolonged screen time increases exposure to media content that promotes such behaviors, thus encouraging alcohol and cigarette consumption. This may indicate that parental supervision of teens' screen time, the activation of parental control options on TV, computer and mobile devices, and the engagement of children in open-air activities could be beneficial both in reducing smoking and alcohol consumption and in increasing levels of physical activity.

Our study showed that the healthiest cluster was the least numerous (7.8%). This group had a remarkable behavioral pattern; although students had very low scores on 'Alcohol drinking' and 'Smoking' behaviors, they also scored low on two health-enhancing behaviors, namely 'Physical activity' and 'Healthy eating'. Clustering patterns of nutrition-related behaviors (such as consumption of raw fruits and vegetables) and alcohol drinking and smoking among Finnish and Swiss adolescents were investigated in a study by Karvonen et al.[38] These authors discerned 3 clusters in both countries: healthy (healthy eating, no smoking, no drinking), unhealthy (unhealthy eating, smoking, drinking) and mixed (unhealthy eating, no smoking, no drinking). Notably, in Switzerland, inclusion in Cluster 3 was more typical of Italian-speaking teens than of German- and French-speaking ones. The third 'mixed cluster' almost corresponds to our 'Quasi-healthy' group; thus, our results confirm that this cluster is cross-culturally valid. Moreover, this finding also supports the conclusion of Wiefferink et al.[19] that teenagers have a complex lifestyle paradigm, in that a substantial proportion of them have a somewhat mixed lifestyle that combines healthy and unhealthy behaviors.

What this study adds

Health-compromising behaviors are common among Tuscan teens, and their combination is thus highly plausible. In turn, these multiple health-related behaviors contribute to determining the lifestyle of adolescents that will reflect their health in the future. To our knowledge, the present study is among the first conducted in Italy to investigate clustering patterns of multiple health-related behaviors in a regionally representative sample of teenagers. Indeed, no studies carried out in Italy were identified in a scoping review of this topic.[29] A down-to-earth appraisal of the clustering of health behaviors would enable integrated, multidimensional health-promotion strategies to be designed and implemented. The results of the present research may serve as a basis for more tailored school-based preventive interventions in Tuscany and, probably, at the supra-regional level.

Limitations of this study

Despite its large sample size, regional representativeness and analysis of various health-related behaviors, our study has some limitations. First of all, owing to its cross-sectional nature, it could not establish any temporal or cause-and-effect relationships; future longitudinal studies will help to highlight temporal trends in the clustering of health-related behaviors among adolescents as well as changes in the composition of the clusters over time. Second, the study was prone to the social desirability bias, in that some students might have under-reported their health-compromising behaviors. However, we believe that the impact of the social

desirability bias was mitigated by the fact that research staff, rather than teachers, played a 'dominant' role in survey administration, since the close involvement of teachers may diminish students' perceived anonymity.[39] Third, Tuscany is a large Italian region situated in central Italy; owing to the well-known North–Center–South gradient among Italian regions in several parameters, including health-related ones[40] (central regions being a transition area), it is unknown whether our results can be generalized to non-central Italian regions.

Conclusions

Early and mid-teenagers in Tuscany form distinct clusters and most of them engage simultaneously in >1 unhealthy behavior. This fact will undoubtedly contribute to compromising the health of the next generation in Italy. This means that parents, teachers, pediatricians, public health practitioners and other relevant stakeholders should urgently plan and implement health-promotion interventions that are not only multidisciplinary but also, considering the observed clustering pattern, equity-based. Given that traditional methods of health promotion often yield only modest benefits, and that today's adolescents readily take up novel technologies,[41] eHealth- and mHealth-based interventions should be viewed as valuables complementary means. Indeed, exploiting appropriate media (such as social networks) to address the present generation of adolescents (the first to have 'grown up online')[41] in their own language could improve their health in the future and 'de-cluster' the observed trend.

Authors' contributions

GL designed and coordinated the study; RS collected data, made quality control checks and collaborated in writing the manuscript; AP performed the statistical analyses and evaluated the results; GL, DP, AD, LA, MVG, DA and RG discussed and interpreted the results and wrote the manuscript. All authors read and approved the final manuscript.

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